A new cross sectional echocardiographic method for estimating the volume of large pericardial effusions

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Abstract

Objective—To evaluate a new cross sectional echocardiographic method for estimating the volume of pericardial effusions.

Design—The volume of pericardial fluid removed by surgical drainage or paracentesis was compared with the volume estimated by the echocardiographic method. The pericardial sac volume and cardiac volume were calculated by applying the formula for the volume of a prolate ellipse ($\pi \times 4/3 \times L/2 \times D1/2 \times D2/2$) where L is the major axis and D1 and D2 are the minor axes. The pericardial fluid volume was calculated as the pericardial sac volume minus the cardiac volume.

Patients—13 patients with 14 large pericardial effusions (one recurrence) all of whom had tamponade and cross sectional echocardiography just before therapeutic full drainage of the effusion.

Results—The volumes of pericardial fluid drained ranged from 0·5 to 2·1 l. The correlation between these actual volumes and the volumes estimated by echocardiography was excellent ($r = 0.97$); the correlation was good in four patients with intrapericardial adhesions.

Conclusions—Because of certain approximations in measuring quantity of pericardial fluid drained, the echocardiographic estimations cannot be claimed to be definite. The data, however, indicate that the echocardiographic method is sufficiently reliable to provide useful estimates for practical clinical purposes.

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The pioneering work of Feigenbaum *et al*[1] established cardiac ultrasound as the procedure of choice for imaging pericardial effusions, Feigenbaum *et al* also described exaggerated cardiac motion in large pericardial effusions.[2]

Since the landmark paper by Horowitz *et al*, it has been common echocardiographic practice to grade the size of pericardial effusions as small, moderate, or large[3] on the basis of the width of the sonolucent pericardial space posterior and anterior to the heart on the M mode echocardiogram. Attempts to estimate the quantity of pericardial fluid from the M mode echocardiogram by cubing the widths of the pericardial sac and of the heart and then subtracting the heart volume from the pericardial sac have yielded conflicting results. Correlation between such estimates of effusion and the actual quantity of pericardial fluid removed at cardiothoracic surgery was reported as good by Horowitz *et al*[3] and by Parameswaran and Goldberg[4] but poor by Prakash *et al*.[5]

We evaluated a simple cross sectional echocardiographic method to estimate the volume of large pericardial effusions.

Patients and methods

Our series of 13 patients all had large pericardial effusions and clinical evidence of tamponade. Six other patients were excluded because the echocardiograms were of inadequate quality. Haemodynamic evidence of tamponade was available in eight. All pericardial effusions were drained therapeutically, either surgically (subcostal pericardial window) in seven instances or percutaneously with tube drainage in seven instances. In 10 patients the pericardial effusion was drained within three hours of the echocardiogram; in the other four the interval was 4–12 hours. All the effusions were drained as completely as possible—that is, until no more fluid was obtainable. In one patient, a large pericardial effusion recurred five months after complete initial drainage, and was drained again.

The aetiology of pericardial effusions was as follows: coronary bypass surgery (three), aortic valve replacement on anticoagulant (two), pulmonary embolism on anticoagulant (one), lung carcinoma (two), renal cell carcinoma (one), collagen disease (one), *E coli* endocarditis (one), aetiology uncertain (two). Echocardiography was performed with Hewlett-Packard (77020 A) equipment and a 2·5 MHz phased array transducer. All measurements were made directly on the videoscreen image by the computerised software measurement package; and then each video image together with the dimensions measured and digital readout was documented on hard copy. Figure 1 shows the cross sectional echocardiographic dimensions that we measured.
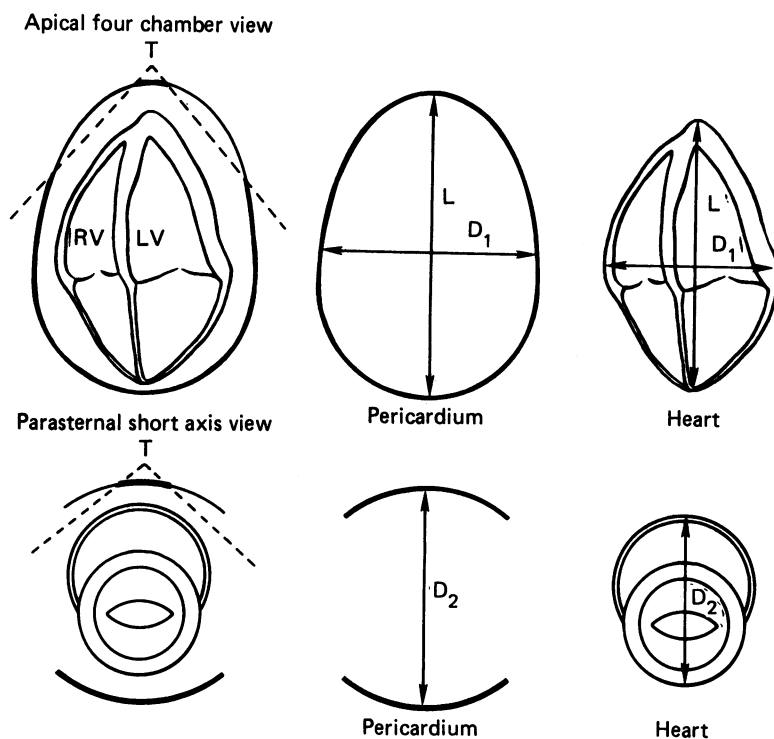
Apical four chamber view

Figure 1 Diagram showing how the major axis (L) and minor axes D1 and D2 were measured in the pericardium and heart in the apical four chamber view and parasternal short axis view. T, transducer; RV, right ventricle; LV, left ventricle.
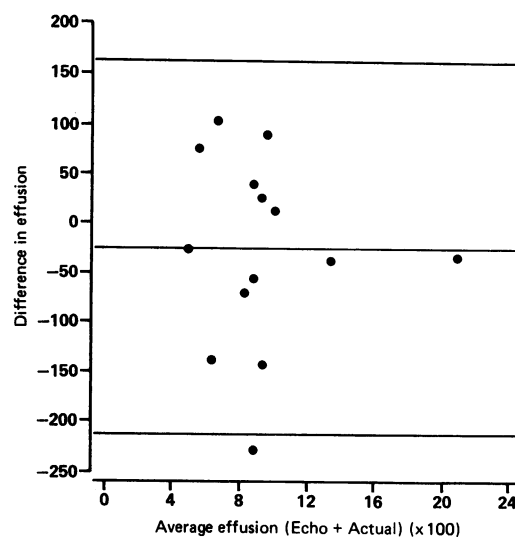

Figure 3 Agreement between the echocardiographically estimated and drained volumes of pericardial effusions calculated by the Bland and Altman method.[6]

PERICARDIUM

We measured the maximal long axis dimension (L) and maximal transverse dimension (D1) in the apical four chamber view and maximal anteroposterior dimension (D2) in the parasternal long or short axis view at the mitral leaflet level.

HEART

Length (L) (maximal long axis dimension) was measured from the tip of ventricular apex to the cephalad border of atria at the junction of right and left atrium in the apical four chamber view; D1 (maximal transverse dimension) was measured in the apical four chamber view, which was usually obtained at the level of the mitral and tricuspid leaflets, 1 to 3 cm on the ventricular side of the atrioventricular valve annuli; D2 (maximal antero-posterior dimension in the parasternal long or short axis view) was measured at the mitral

leaflet level. Three to six measurements were made of each dimension on different cardiac cycles and the mean of each dimension was calculated. All measurements were made at the onset of the QRS complex. Pericardial measurements were made from inner border to inner border. Cardiac measurements were made from epicardium to epicardium. Care was taken to avoid side-lobe artefacts simulating epicardial echoes. The observer making the echocardiographic measurements was unaware of the quantity of pericardial fluid drained. The volumes of the pericardial sac and heart were calculated by applying the formula for volume of a prolate ellipse: $\pi \times 4/3 \times L/2 \times D1/2 \times D2/2$, where L is the major axis and D1 and D2 the two minor axes. The pericardial fluid volume was calculated as the pericardial sac volume minus cardiac volume.

Results

The echocardiographically estimated volume of pericardial fluid correlated well (fig 2) with the volume of pericardial fluid drained (r = 0·97). Data from the two patients with the largest pericardial effusions made a large contribution. When the patient with the largest effusion (2·1 l) was excluded, the r value fell to 0·93, and when this patient and the patient with the next largest effusion (1·35 l) were excluded, the r value fell to 0·88.

The agreement between the two measurement methods was calculated by the Bland and Altman method.[6] The limits of agreement for the volume of pericardial effusion (echocardiographic minus drained volume) were −211·72 and 161·86 ml (fig 3).

The two patients in whom the echocardiographic method underestimated the amount of the pericardial fluid to the largest extent (230 and 144 ml) had the most conspicuous atrial compression, such that the atrial free walls appeared concave rather than convex on the cross sectional echocardiogram in the apical four chamber view.

Intrapericardial adhesions at the cardiac

Figure 2 Correlation between amount of pericardial fluid drained and echocardiographically estimated pericardial effusion.
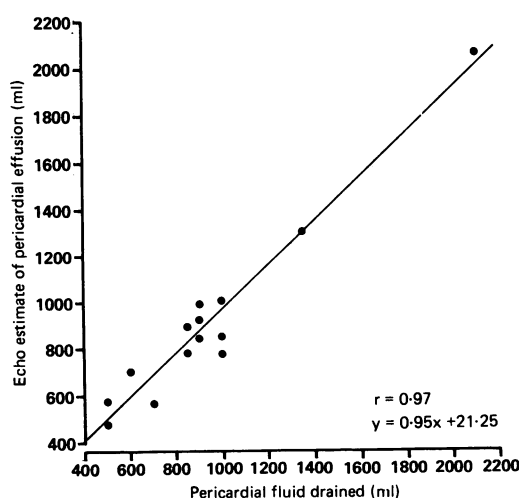
r = 0·97
y = 0·95x +21·25

Figure 4 Cross sectional
echocardiogram of a
patient with a large
pericardial effusion and
tamponade. In the apical
four chamber view (left)
the dimensions P-P are the
major axis (L) and minor
axis D2 of the pericardial
sac; the corresponding
cardiac dimensions are
labelled C-C. Side lobe
artefacts adjacent to the
left ventricular and right
ventricular free walls must
be recognised. The
parasternal short axis view
(right) shows the minor
axis D2 of the pericardal
sac (P-P) and the heart
(C-C).
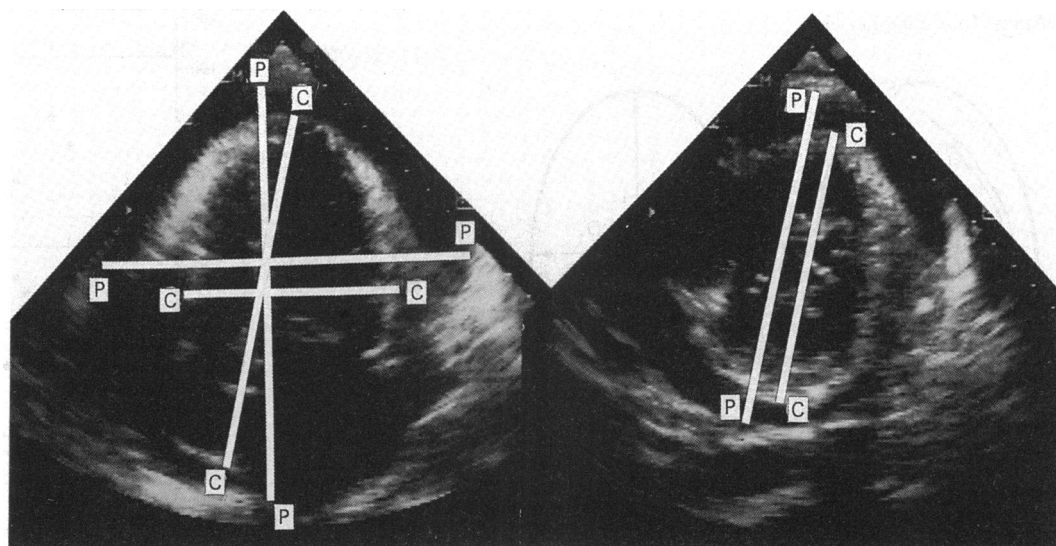
apex, with or without involvement of a small amount of the adjacent anterior wall, were seen on cross sectional echocardiography in three patients. In one other patient extensive pericardial adhesions had sealed off the whole anterior cardiac surface so that the large pericardial effusion was entirely loculated posteriorly; the echocardiographic estimate of the pericardial effusion (1012 ml) was very close to the actual quantity of fluid drained (1 l).

Discussion

Clinicians need to know the approximate volume of a pericardial effusion to help make management decisions about draining the effusion and discharging the patient from hospital and to ascertain whether the effusion is increasing, decreasing, or unchanged in quantity on serial echocardiograms.

At present pericardial effusions are commonly graded by size as small, moderate, or large. However, these terms have widely different meanings to different echocardiographers. For example, some regard pericardial effusions of <500 ml as small, those between 500 and 1000 ml as moderate, and those >1000 ml as large[7]; Arvin described effusions of 150–400 ml as moderate and those of 500–2000 ml as large[8]; Menapace regards effusions of 25–100 ml as small, those of 100–500 ml as moderate, and those >500 ml as large.[9] Further ambiguity has been introduced by the use of terms such as "moderately large" or "moderate-to-large" effusions.

Unlike the left ventricle, the fluid-filled pericardial space between the heart and parietal pericardium does not conform to a simple geometric shape so that extrapolation of one or more dimensions of the pericardial space cannot be expected reliably to estimate the quantity of pericardial fluid. So another approach was attempted to estimate the total pericardial volume and the volume of the heart (from the M mode echocardiogram by simple cubing of the short axis dimension) and subtracting the estimated cardiac volume from the total pericardial volume to obtain the volume of the

met with qualified success[3 4] but not for others.[5] Horowitz et al found a correlation coefficient of 0·98 in 12 patients, but this fell to 0·41 when the two patients with largest effusions were excluded.[3] Parameswaran and Goldberg reported a correlation coefficient of 0·78 in 23 patients.[4]

Cross sectional echocardiography of pericardial effusions of varying sizes showed that pericardial fluid was not uniformly distributed around the heart in circumcardiac effusions[1 10 11]; it also showed an even greater asymmetry of pericardial fluid accumulation when there were intrapericardial adhesions or fluid loculations.[12 13] M mode echocardiograms, which give an ice-pick view in the antero-posterior dimension only, might therefore be expected often to overestimate or underestimate pericardial effusion volume, especially since cubing of the dimensions (cardiac and pericardial) would magnify errors secondary to disparities in pericardial width. To our knowledge, few if any echocardiography laboratories use this M mode method to report volume estimates of pericardial effusions in routine clinical practice.

The pericardium is sometimes described as a conical flask-shaped structure with its base on the diaphragm and the great vessels emerging from the "mouth" of the flask. This may be true of the unopened fibrous pericardium as viewed in situ. When it is imaged by cross sectional echocardiography, however, the serous pericardial sac is ellipsoidal, whether or not it contains an effusion.

We assumed that the heart too is ellipsoidal and hence we used the same formula to estimate its volume.

In patients with conspicuous biatrial compression caused by tamponade,[14 15] which is particularly manifest at the onset of the QRS complex, the contour of the atria may be concave rather than convex so that the estimated cardiac volume is larger (and the quantity of pericardial fluid smaller) than actual amount present. This is the most likely reason why our echocardiographic method underestimated the quantity of pericardial effusion in two patients.

The volume of pericardial fluid estimated by our echocardiographic method correlated well with the actual quantity of fluid drained. Although the very high correlation coefficient (0·97) was in part due to the two patients with pericardial effusions that were much larger than the rest, the correlation remained quite good (r = 0·88) even when these two patients were excluded.

The presence of intrapericardial adhesions or loculation in four patients did not preclude a good correlation between the amount of pericardial fluid drained and our echocardiographic estimate. We have previously called attention to potential pitfalls in the M mode grading of pericardial effusions by size in patients with intrapericardial adhesions.[16]

In a review article on echocardiography in pericardial disease, Schiller briefly mentioned having used cross sectional echocardiography in "a few" patients to measure the volume of pericardial contents.[17] He used a light-pen computational system to outline the borders of the pericardium and of the heart in the apical four chamber view. Volumes were computed electronically by an area-length single-plane algorithm. Schiller pointed out that an unavoidable shortcoming of this approach is that the pericardial border near the apical region cannot be visualised because it falls outside the narrow part of the fan-shaped sector image. However, non-visualisation of this portion of the pericardial outline does not interfere with measurement of the pericardial dimensions required for estimation of pericardial volume by our method (fig 4).

We are aware of certain shortcomings of this study, but believe them to be minor. The quantity of pericardial fluid was not measured precisely to the millilitre but "rounded off" to the nearest 50 ml. When the pericardial fluid was drained surgically we know that the entire pericardial contents were removed. We believe that the inevitable loss of a small amount of pericardial fluid (not included in the measured quantity) at the beginning of the drainage procedure was less than 50 ml and often less than 25 ml. When the effusions were drained by paracentesis and tube drainage we may not have obtained and measured all the epicardial fluid. In nine of the patients we had echocardiograms in multiple views obtained immediately after drainage in six and within 18 hours in three. In all of these no pericardial effusion was visualised or only a small posterior pericardial pool no more than 5 mm deep and no more than 2·5 cm in diameter. We therefore think it reasonable to assume, for practical purposes, that all (or almost all) of the pericardial effusion had been drained off and measured. Our echocardiographic method does not take into account accumulation of fluid in the various minor pericardial recesses.

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